AQUALINC RESEARCH LIMITED

Manor Burn Catchment Detailed Hydrology

Prepared for the Manuherikia Catchment Water Strategy Group

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Prepared by:	Peter Brown		
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www.aqualinc.com

CHRISTCHURCH PO Box 20-462, Bishopdale 8543, Christchurch ♦ Phone: (03) 964 6521 ♦ Fax: (03) 964 6520
HAMILTON PO Box 14-041, Enderley 3252, Hamilton ♦ Phone: (07) 858 4851 ♦

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EXECUTIVE SUMMARY

Hope Creek dam

Hope Creek dam has a potential annual average yield of 15 Mm^3. This is 75% of the potential yield of the Upper Manor Burn dam. Fifteen years of near continuous flow data is available for the Hope Creek, near the proposed dam site. This data means we have considerable confidence in the potential catchment yields.

Hope Creek dam could potentially supply an average of 13 Mm^3 per year to Ida Valley. In all but the driest of years, at least 10 Mm^3 per year would be able to be supplied. In wet years, when the Upper Manor Burn dam was spilling, Hope Creek water would not be used. The limited storage in the Hope Creek dam means Hope Creek, Upper Manor Burn and Pool Burn dams would need to be managed together. Hope Creek water would be used first, with the dam being drawn down to the minimum level most years. The Upper Manor Burn and Pool Burn dams store water for several seasons, and in dry years, a greater proportion of water would come from these dams. This additional water would allow an additional 2,500-3,000 ha to be fully irrigated in the Ida Valley.

15 Mm^3 of usable storage would ensure the majority of Hope Creek dam yields are able to be ultilised. A dam water level operating range of about 632 – 644 m amsl would provide 15 Mm^3 of storage. This would require about a 32 m high dam. A 13 to 15 m pumping lift would be necessary to lift water from the minimum lake operating level, to the height of the conveyance race. Raising the dam an additional 2 m, would reduce the pumping lift by about 4 m.

There is some uncertainty in the Hope Creek Dam stage – storage relationship because of the shape of Stone Hut Flat and availability of only 20 m contours. To improve the stage – storage relationship we recommend a high resolution aerial photogrametry, LIDAR, or GPS topographic survey be undertaken prior to finalising any design.

A 1 in 500 year flood at Hope Creek would have a peak in flow of about 60 m^3/s. Dam flood storage may significantly reduce peak flows; the degree of reduction would depend on the spillway hydraulic characteristics.

While we do not expect reservoir leakage to be significant, this would require investigation prior to finalising designs.

Galloway dam supply

Both a new dam upstream of the existing Lower Manor Burn dam, or on Little Valley Creek West, could provide the Galloway Irrigation Scheme with an alternative water supply to pumping Manuherikia River water.

A new Lower Manor Burn dam would refill every year. 5 Mm^3 of usable storage should be sufficient to meet Galloway Irrigation Scheme demand. If the dam were located 400 m upstream of the existing dam, a maximum dam water level of 169 m amsl would provide 5 Mm^3 of usable storage. This would require about a 20 m high dam. The disadvantage of this dam site is it would affect the existing natural ice skating rink. If the dam were instead constructed 1.4 km upstream of the existing dam, upstream of the natural ice skating rink, the maximum dam water level would need to be 174 m amsl in order to provide 5 Mm^3 of usable storage. This would require about a 25 m high dam.

The Little Valley Creek West dam would require about 12 Mm^3 of usable storage. This would require about a 25 m high dam. A disadvantage of this dam site, compared to the Lower Manor Burn dam option, is 170 to 200 ha of flat farmland would be inundated. The dam would not refill every year consequently could be susceptible to supply difficulties if climate change resulted in a shift to a drier climate. If this dam site were favoured, we recommend a flow recorder site be set up near the dam site, and flows be recorded for a minimum of three years.

There is considerable uncertainty in the Little Valley Creek West stage – storage relationship because of the shape of the basin and availability of only 20 m contours. To improve the stage – storage relationship we recommend a high resolution aerial photogrametry, LIDAR, or GPS topographic survey be undertaken prior to finalising any design.

A 1 in 500 year flood at the Lower Manor Burn dam and at Little Valley Creek West dam would have a peak in flow of about 210 m^3/s and 30 m^3/s, respectively. For the Little Valley Creek West dam, flood storage may significantly reduce peak flows; the degree of reduction would depend on the spillway hydraulic characteristics.

While we do not expect reservoir leakage to be significant, this would require investigation prior to finalising designs.

1 Hope Creek Dam

1.1 Background

The idea of supplementing the Ida Valley irrigation scheme with Hope Creek water dates from at least the early 1920's (Public Works Department 1923). Hope Creek proposals were revived in the late 1940's and 1950's, following 10 years where Upper Manor Burn and Pool Burn combined yields averaged only 22 Mm^3/y; 32% less than allocated and 31% less than average yields prior to 1945. The most promising of these proposals was a dam on Hope Creek at the downstream end of Stone Hut Flat. As part of these investigations a flow recorder was installed near Stone Hut. Further details on these investigations is provided by Reid (1966) and Reid and Grant (1979).

1.2 Hope Creek flow at Stone Hut

Flow data comes from a weir site in Hope Creek located 600 m downstream of Stone Hut. A temporary weir was installed in February 1950, a permanent one a few months later, and a recorder in January 1951. Readings commence with the recorder installation at the beginning of 1951, although occasional staff gauge readings were taken prior to this, and are available to May 1965. In all over this 168 month period, 4867 days of record are available, 9 months having no worthwhile record and 14 months with incomplete records. Daily level readings were converted to flows using the weir's stage – discharge relationship (Reid 1966).

Recorded flows are illustrated in Figure 1, Figure 2 and Figure 3. Catchments for the recorder and proposed dam are shown in Appendix A.

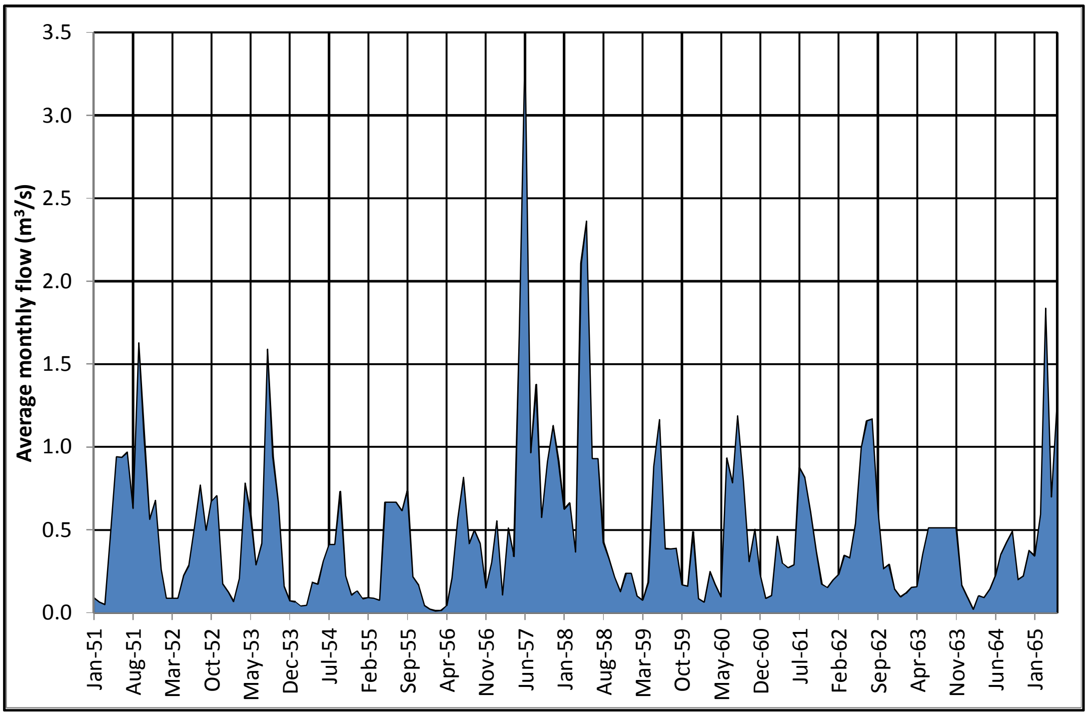

Figure 1: Hope Creek flow at Stone Hut weir

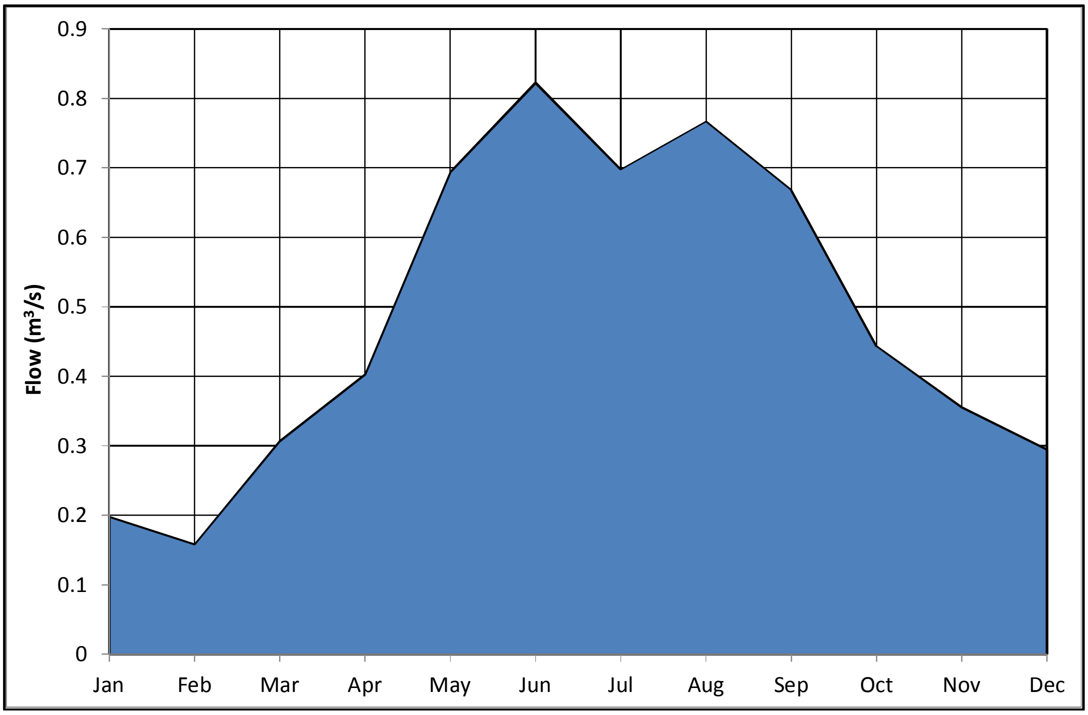

Figure 2: Hope Creek average monthly flow at Stone Hut weir

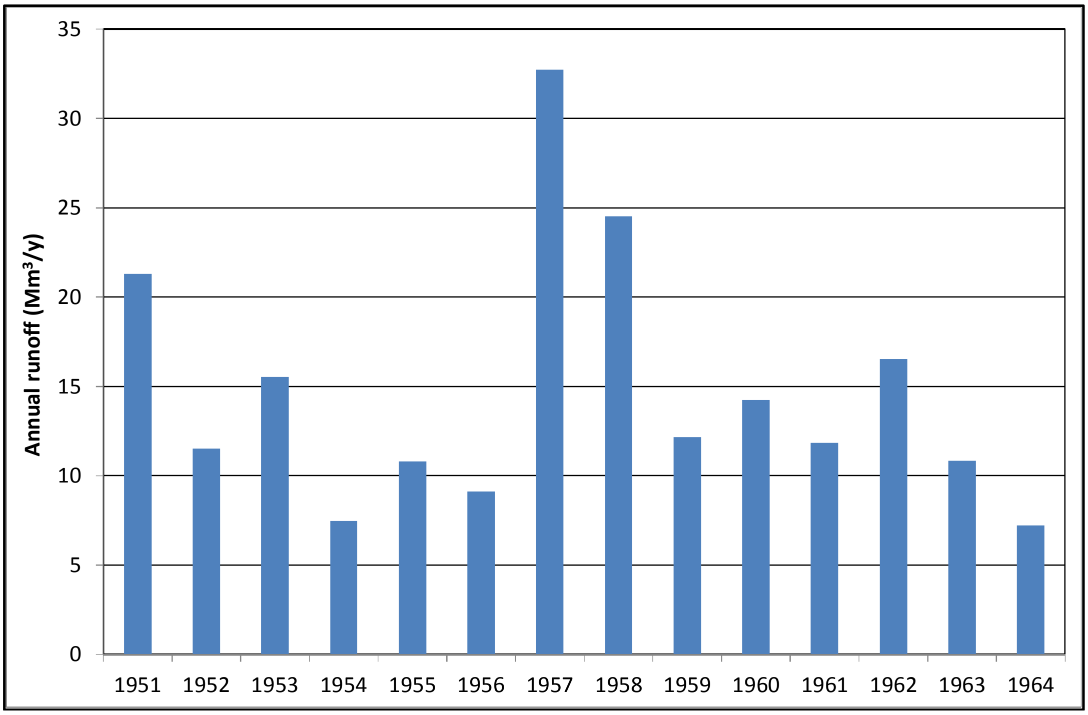

Figure 3: Hope Creek annual yield at Stone Hut weir

1.3 Dam storage

Hope Creek dam storage was estimated from Land Information NZ 1:50,000 topographic maps. The stage – storage relationship is shown in Figure 4. The revised relationship indicates there is slightly less storage available compared with first order estimates from the Stage 2 report (Aqualinc 2012b). There is some uncertainty in the stage – storage relationship because of the shape of Stone Hut Flat and availability of only 20 m contours. We recommend a high resolution aerial photogrametry, LIDAR, or GPS topographic survey is undertaken prior to finalising any design.

An aerial photograph of Stone Hut Flat is included in Appendix B.

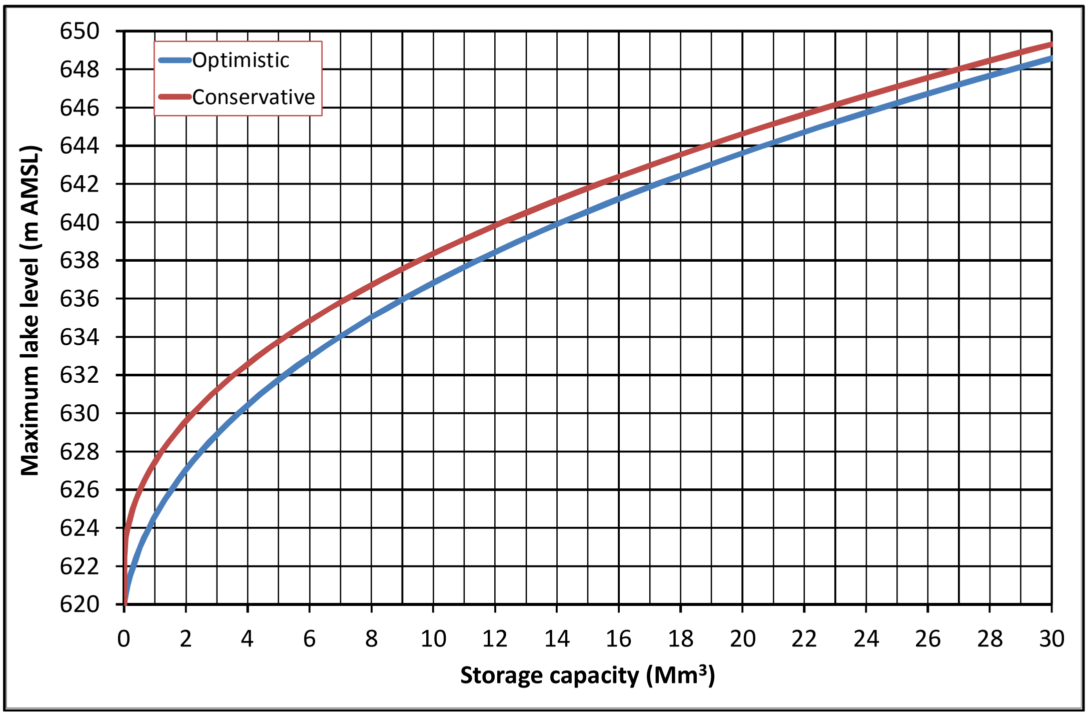

Figure 4: Revised Hope Creek stage – storage relationship

1.4 Long term trends

Hope Creek flow records extend from 1951 to 1965. Flows during this period are likely to be slightly below the long term average. The period from 1946 to 1956 was unusually dry. During this period Ida Valley rationing averaged only 60% of quota. The flow record also contains two wet years: 1957 and 1958.

In general, the Manuherikia catchment was slightly drier during the mid 1940's to 1970's, and slightly wetter during the 1980's and 1990's (Aqualinc 2012a). Prior to 1945 Upper Manor Burn and Pool Burn dam yields were higher than average, with moderate rationing only being required 3 years in 27. Upper Manor Burn dam yields from 1918 to 1945 average 24.5 Mm^3/y, compared with an average yield of 19.8 Mm^3/y from 1945 to 1977 (Reid 1979). Figure 5 illustrates that the Hope Creek flow record is reasonably representative of this drier period from 1945 to 1977.

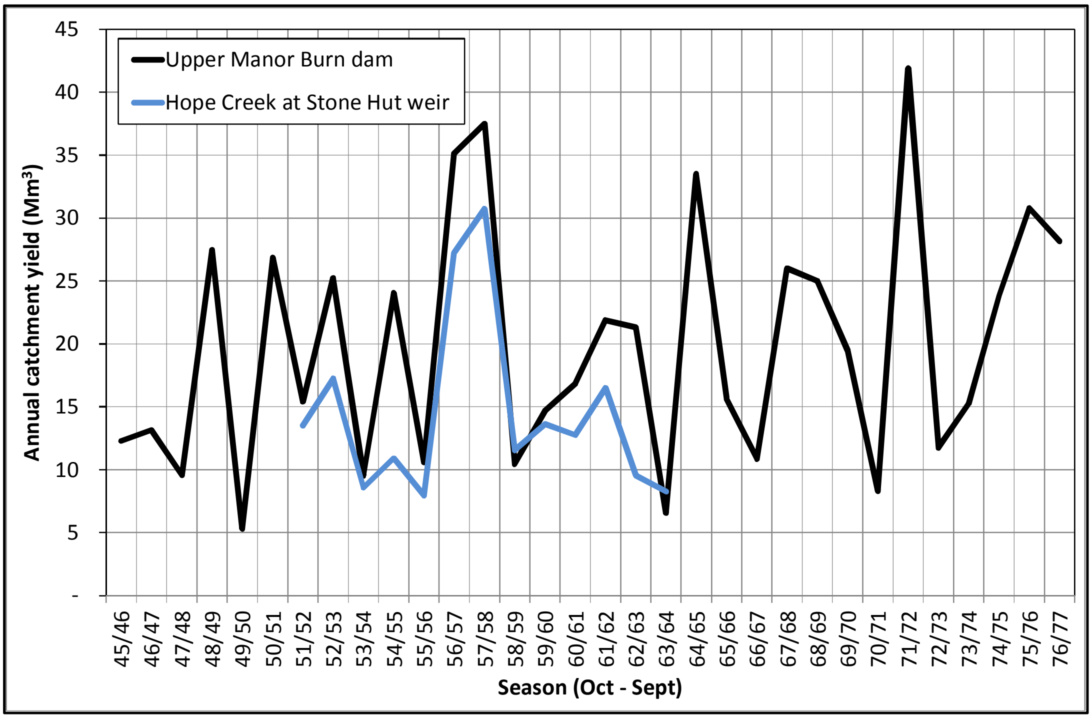

Figure 5: Comparison between Hope Creek and Upper Manor Burn dam yields

The droughty nature of the Manor Burn and Pool Burn catchments means Ida Valley irrigation scheme is particularly vulnerable to long term climate trends. In subsequent modelling we have used the Hope Creek flow records from 1951 to 1965. Results are likely to be representative of slightly drier than average long-term conditions.

1.5 Hope Creek Dam vs Upper Manor Burn Dam yields

For the period from 1951 to 1965, Upper Manor Burn dam yield's averaged 19.2 Mm^3/y. During the same period flow at the Hope Creek Stone Hut weir averaged 14.5 Mm^3/y; 75% of the Upper Manor Burn dam yield.

Higher Upper Manor Burn compared with Hope Creek yields can be attributed to higher run-off per unit area and a slightly larger catchment. From Table 1 and Table 2 we estimate that the run-off per unit area for Hope Creek is only 82% of the Upper Manor Burn catchment.

At the proposed Hope Creek dam site we expect yields to be similar to flows at the Stone Hut weir. The dam site catchment is about 10 km^2 greater than at Stone Hut weir, resulting in about 8% or 1.2 Mm^3 additional inflow [estimate from NIWA water resource explorer]. Additional gains will however be off-set by about 0.6 Mm^3 of lake evaporation losses (Table 1) and dam leakage losses (assumed to be 0.6 Mm^3). While we do not expect reservoir leakage to be significant, this would require investigation prior to finalising designs.

In conclusion, yields at the proposed Hope Creek dam site are expected to average about 75% of Upper Manor Burn dam yields. This corresponds to an annual average yield of 15 Mm^3 for the period from 1945 to 1977, or 17 Mm^3 for the period from 1918 to 1977.

Table 1: Hope Creek and Upper Manor Burn net lake evaporation losses

Catchment	Lake area (ha)	Transpiration & evaporation (mm/y)		Net lake evap.(3) (Mm^3/y)
		Lake evap.(1)	Dryland ET (2)	
Upper Manor Burn Dam	663	710	330	2.5
Hope Creek at Dam(4)	145(4)	710	330	0.6

(1) Finkelstein (1973). Estimate derived from pan evaporation measurements at the Upper Manor Burn Dam.
(2) Catchment rainfall – runoff. Estimated from NIWA Water Resource Explorer.
(3) (Lake evap. – Dryland ET) × Lake area × units conversion
(4) Assumes an average lake level of 640 m amsl.

Table 2: Upper Manor Burn and Hope Creek runoff

Catchment	Catchment area (km^2)	Net lake evap.(1) (Mm^3)	Average annual runoff	
			(Mm^3)(2)	(mm/y)(3)
Upper Manor Burn Dam	97	2.5	21.7	224
Hope Creek weir	78	0	14.5	186

(1) Net lake evaporation from Table 1.
(2) Average yield from 1951 - 1965 + net lake evaporation
(3) (2)/catchment area × units conversion

1.6 Dynamic modelling

We constructed a monthly time-step model to investigate the amount of water that could be transferred to the Ida Valley from the Hope Creek dam. The model is illustrated in Figure 6. The model was run from 1951 to 1965; the period when Hope Creek flow data is available.

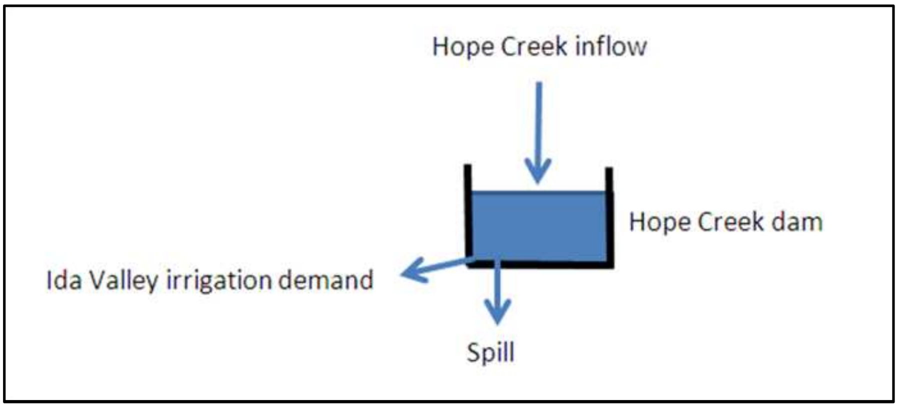

Figure 6: Hope Creek dam monthly time step model

We assumed Hope Creek, Upper Manor Burn and Pool Burn dams would be managed together. Hope Creek water would be used first, with the dam being drawn down to the minimum level most years. We assumed demand would exceed supply in every year other than the 1957/58 season, when the Upper Manor Burn dam was spilling. We assumed water would be conveyed to the Bonanza race between October and April. The demand profile used in modelling is shown in Figure 7.

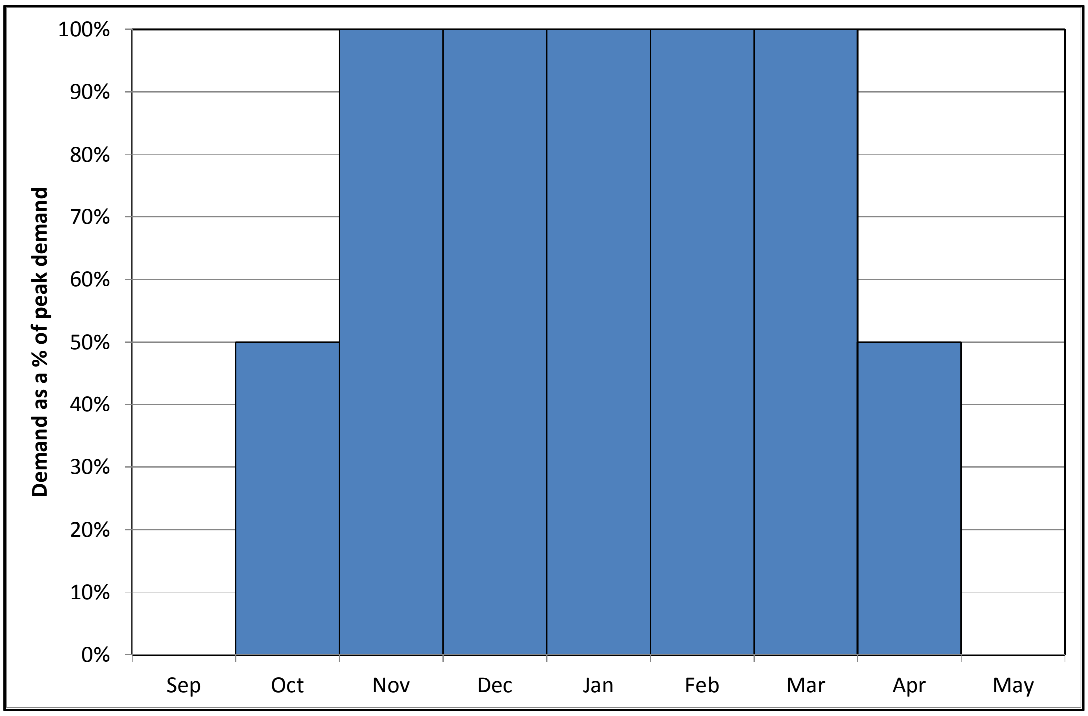

Figure 7: Modelled Ida Valley irrigation demand profile.

We modelled four scenarios:

- Scenario 1: 1.2 m^3/s peak demand & 15 Mm^3 of usable storage;
- Scenario 2: 1.0 m^3/s peak demand & 15 Mm^3 of usable storage;
- Scenario 3: 0.9 m^3/s peak demand & 15 Mm^3 of usable storage; and
- Scenario 4: 1.0 m^3/s peak demand & 20 Mm^3 of usable storage.

Results are shown below. Results indicate the benefits of increasing usable storage from 15 Mm^3 to 20 Mm^3 are small. This additional storage may only be used once every 15 years. Furthermore, additional storage would result in increase in lake evaporation and dam leakage losses, potentially negating any spill reduction benefits. A dam water level operating range of 632 – 644 m amsl would provide 15 Mm^3 of storage. A 13 to 15 m pumping lift would be necessary to lift water from the minimum lake operating level, to the height of the conveyance race. Raising the dam an additional 2 m, would reduce the pumping lift by about 4 m.

Results indicates 1.0 m^3 conveyance capacity from the dam to Bonanza Race should be sufficient.

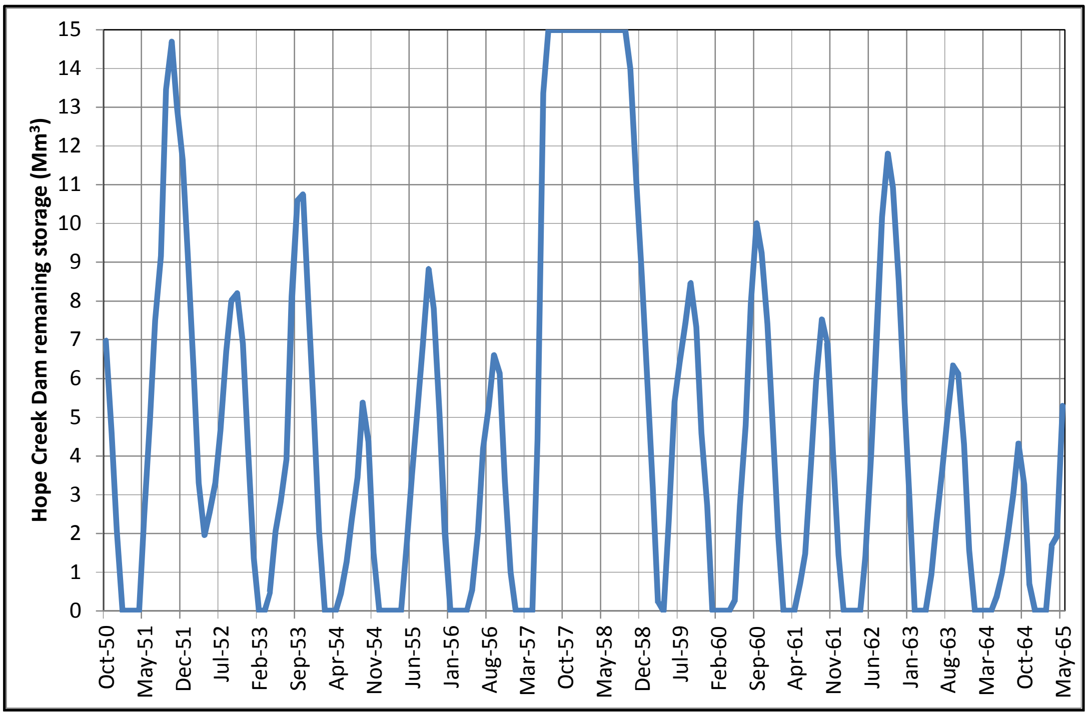

Figure 8: Hope Creek storage dynamics for Scenario 1.

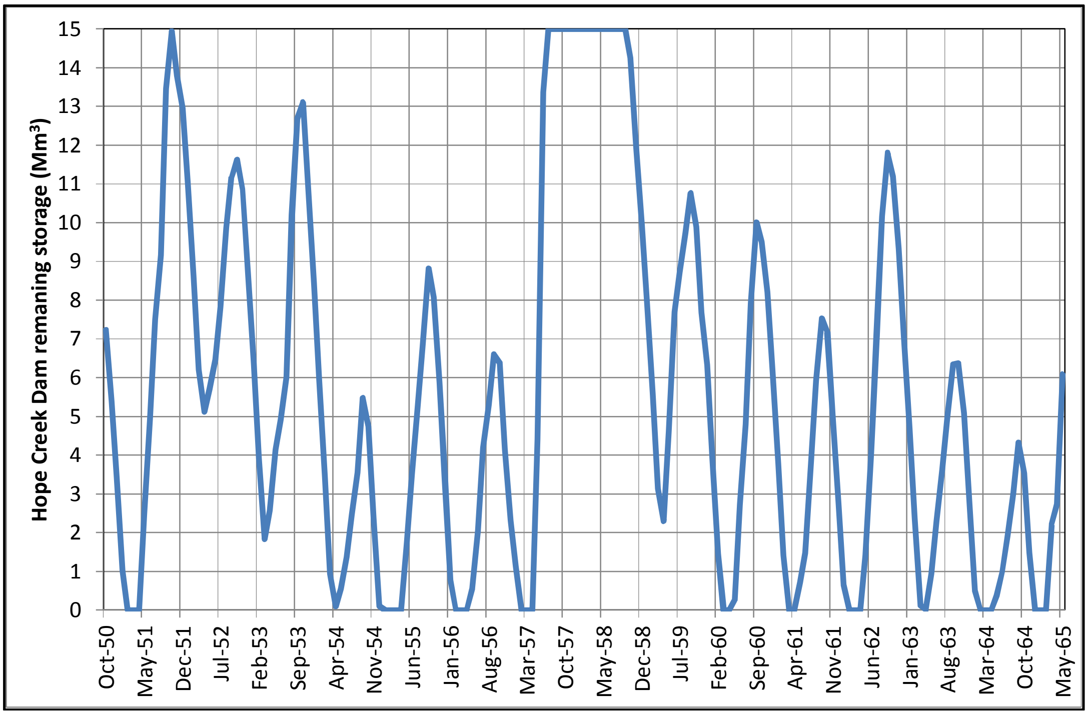

Figure 9: Hope Creek storage dynamics for Scenario 2

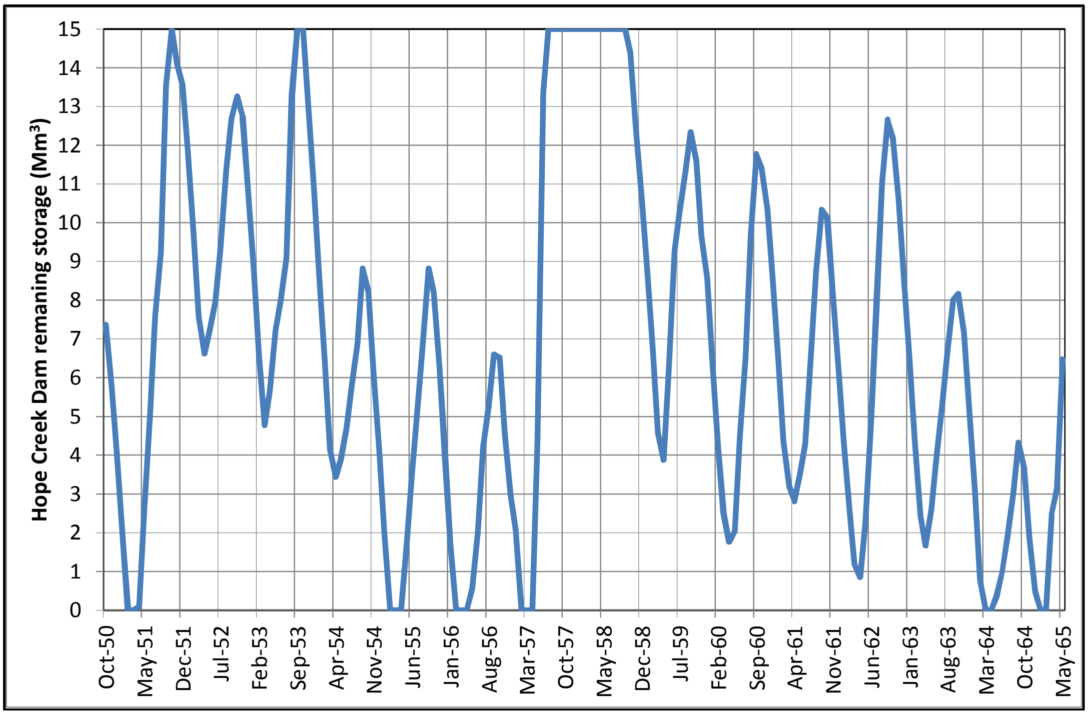

Figure 10: Hope Creek storage dynamics for Scenario 3

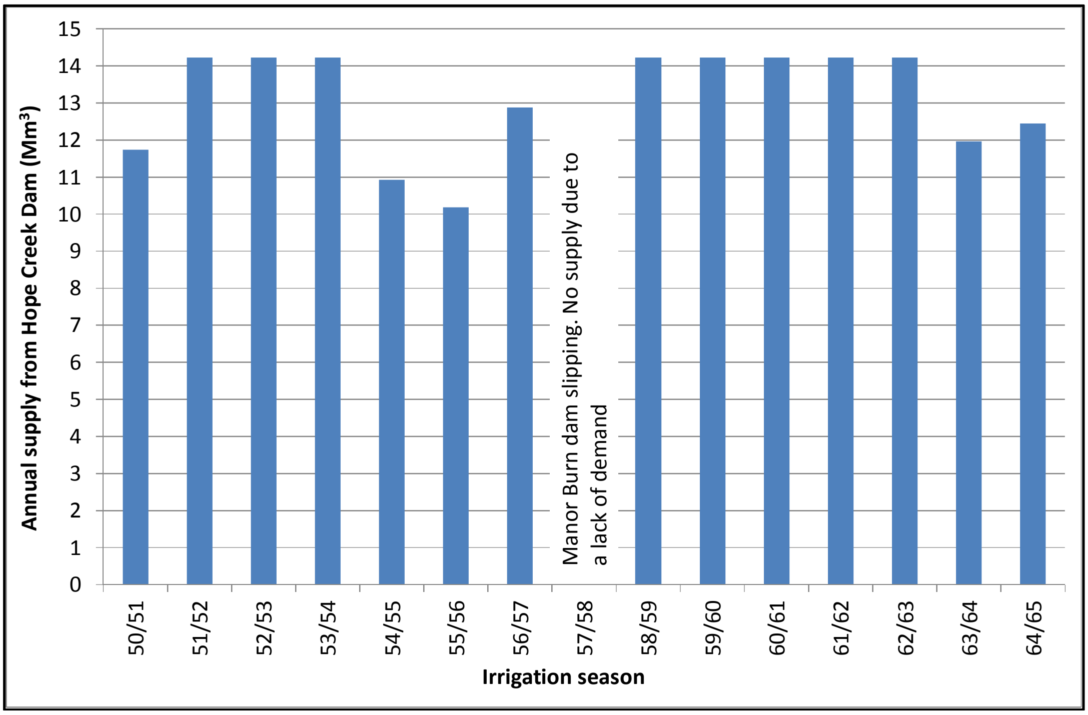

Figure 11: Hope Creek to Ida Valley supply for Scenario 3

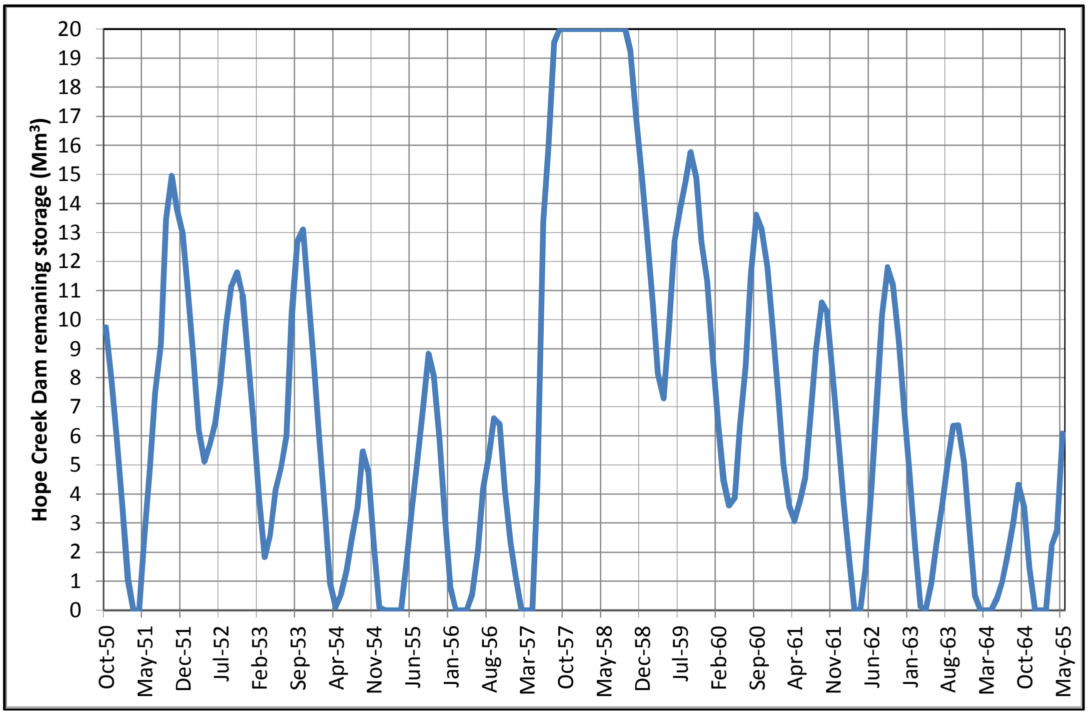

Figure 12: Hope Creek storage dynamics for Scenario 4.

2 Galloway dam supply

2.1 Background

A new dam upstream of the Lower Manor Burn Dam, or a dam on Little Valley Creek West, were identified in the Stage 3a study (Aqualinc 2012c) as a possible source of water to provide a gravity supply to Galloway.

2.2 Flows

To our knowledge, the only record of daily flows in the Manor Burn catchment is in the Hope Creek catchment, at the weir downstream of Stone Hut.

Manor Burn tributary flows were estimated using NIWA's Water Resource Explorer, with the run-off model calibrated to the Hope Creek flow record. Flows are summarised in Table 3.

Table 3: Estimated naturalised Manor Burn catchment yields

Location	Catchment area (km^2)	Annual average yield[1] (Mm^3)	Annual average yield[1] % of total
Upper Manor Burn dam	97	20	30%
Hope Creek dam	88	15	24%
Little Valley Creek West dam	40	6	10%
All other tributaries	275	22	36%
Total	**500**	**63**	**100%**
Total (excl. Hope Creek & Upper Manor Burn)	**315**	**28**	**46%**
(1) For the period 1951 to 1965.			

Because the Manor Burn catchment is quite dry, relatively small changes in rainfall can result in significant changes in run-off. Consequently it is difficult to accurately estimate run-off without a long period of flow records and our yield estimates for the Little Valley Creek West dam and "all other [Manor Burn] tributaries" may only be accurate to ±20%. The dry catchments means yields may also vary significantly in response to long term climate trends.

2.3 Dam storage

Dam storage was estimated from Land Information NZ 1:50,000 topographic maps.

The stage – storage relationship for a new Lower Manor Burn dam is shown in Figure 13. An aerial photograph of the dam site is included in Appendix C.

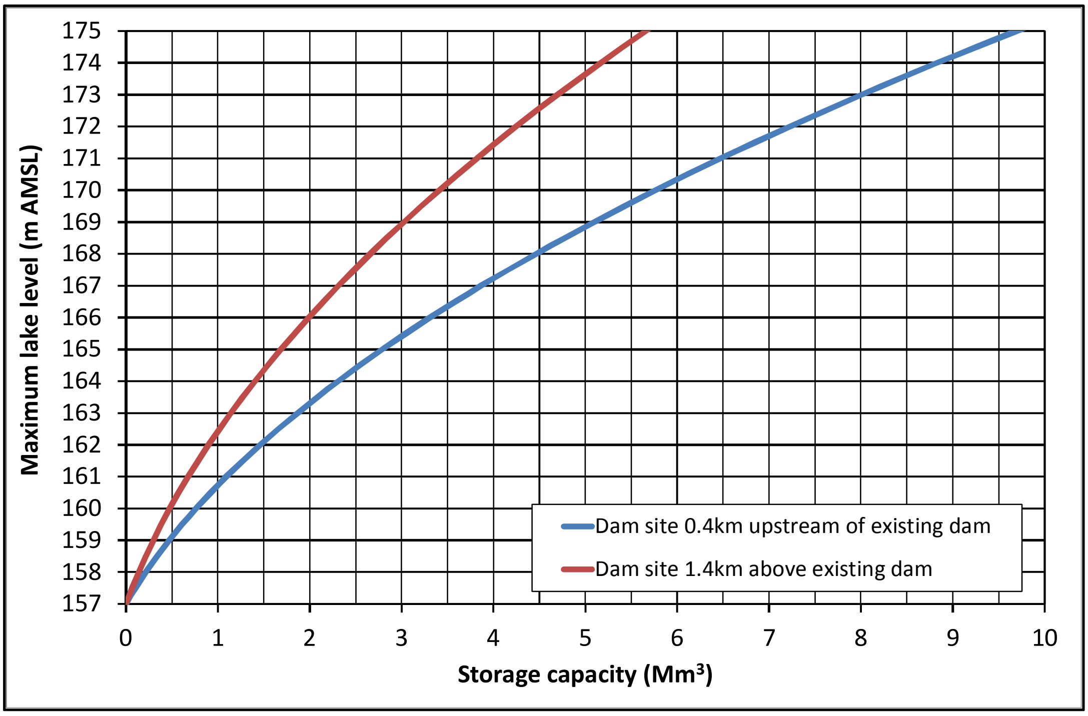

Figure 13: Lower Manor Burn dam stage – storage relationship

The stage – storage relationship for Little Valley Creek West dam is shown in Figure 14. An aerial photograph of the dam site and upstream basin is included in Appendix D. The revised relationship indicates there is less storage available compared with first order estimates from the Stage 2 report (Aqualinc 2012b). There is considerable uncertainty in the stage – storage relationship because of the shape of the basin and availability of only 20 m contours. We recommend a high resolution aerial photogrammetry, LIDAR, or GPS topographic survey is undertaken prior to finalising any design.

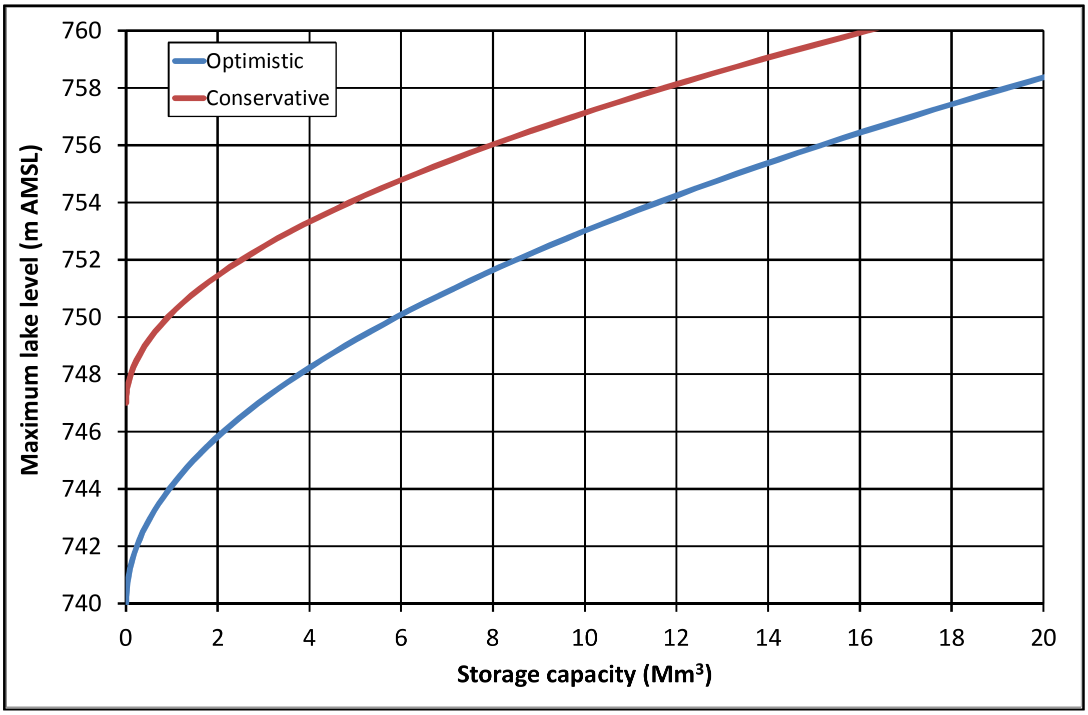

Figure 14: Revised Little Valley Creek West dam stage – storage relationship

2.4 Dynamic modelling

We constructed monthly time-step models of a new dam upstream of the existing Lower Manor Burn dam, and a dam on Little Valley Creek West. The models were run from 1951 to 1965. The Galloway Irrigation Scheme demand profile used in modelling is shown in Figure 15. From Table 8 in the Stage 2 report (Aqualinc 2012b) the peak scheme demand is 440 l/s. The demand profile corresponds to an annual water use of 6.5 Mm3, which equates to 1,225 mm over 530 ha. The models are illustrated in Figure 16 and Figure 17. Key model parameters are given in Table 4 and Table 5. Results are presented in Figure 18 and Figure 19.

The model assumes the Hope Creek dam is constructed and water above this dam would therefore be unavailable at the Lower Manor Burn dam site.

Modelling assumes annual dam and reservoir leakage will be less than 0.5 Mm^3. While we do not expect reservoir leakage to be significant, given the geology, this would require investigation prior to finalising designs.

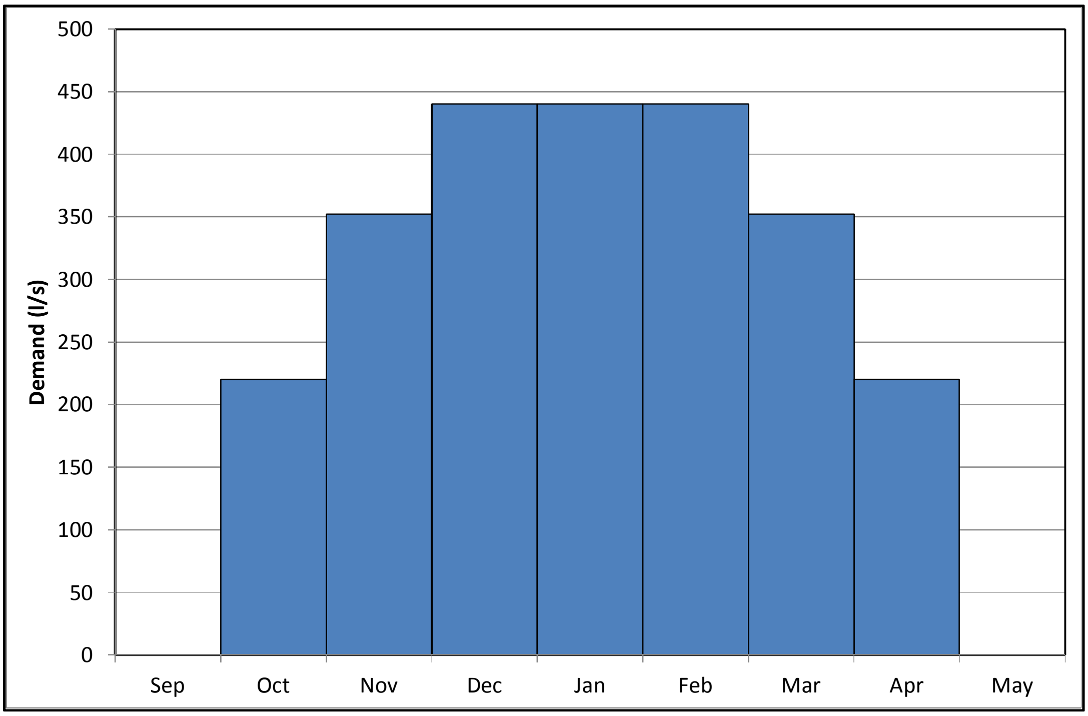

Figure 15: Modelled Galloway irrigation demand

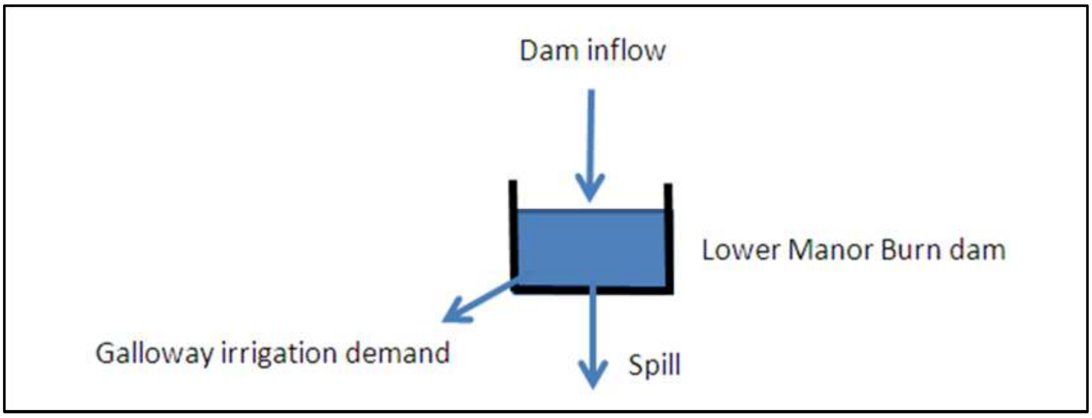

Figure 16: Lower Manor Burn dam monthly time step model

Table 4: Lower Manor Burn dam – key model parameters

Parameter	Value
Usable dam storage	5 Mm^3
Dam inflow	1.9×Hope Creek flow at Stone Hut weir
Net dam evaporation and leakage losses	0.5 Mm^3/y

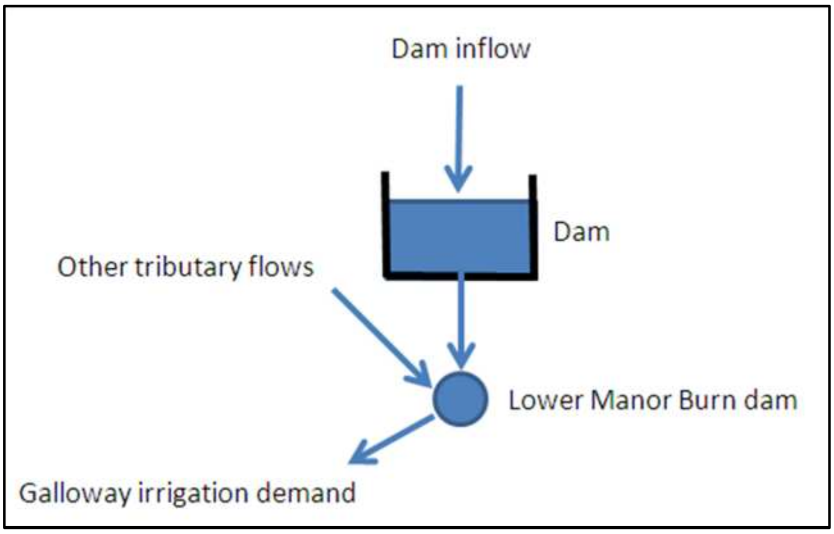

Figure 17: Little Valley Creek West dam monthly time step model

Table 5: Little Valley Creek West dam – key model parameters

Parameter	Value
Usable dam storage	12 Mm^3
Dam inflow	0.4×Hope Creek flow at Stone Hut weir
Other tributary flows	1.5×Hope Creek flow at Stone Hut weir
Net dam evaporation and leakage losses	1.0 Mm^3/y

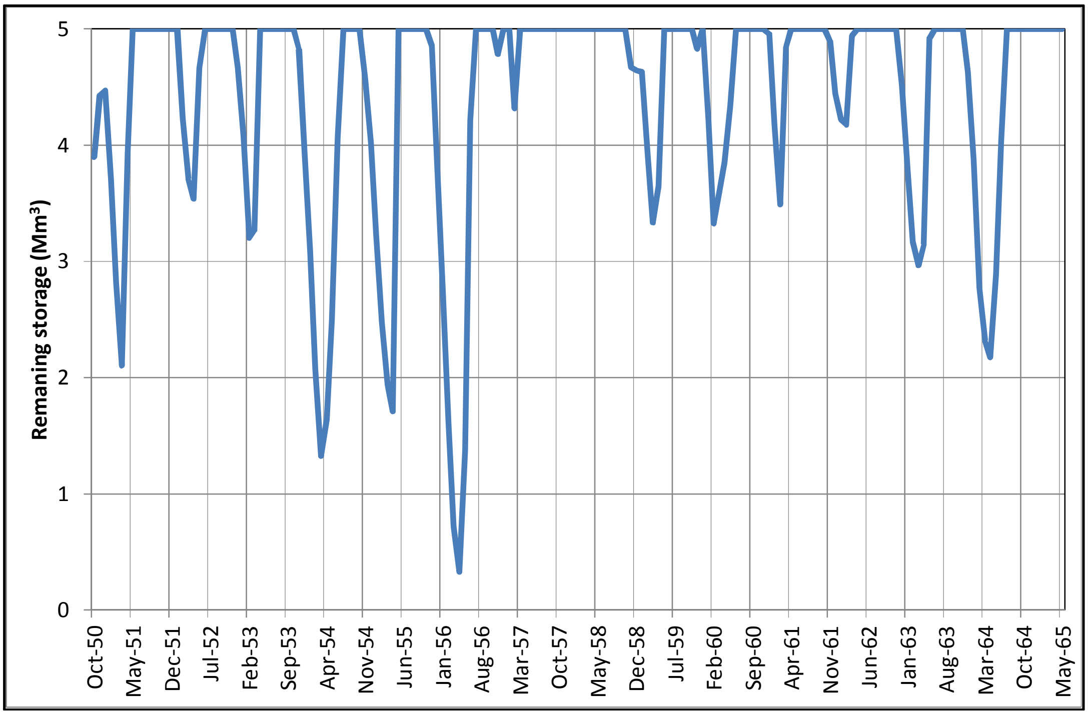

Figure 18: Lower Manor Burn dam storage dynamics

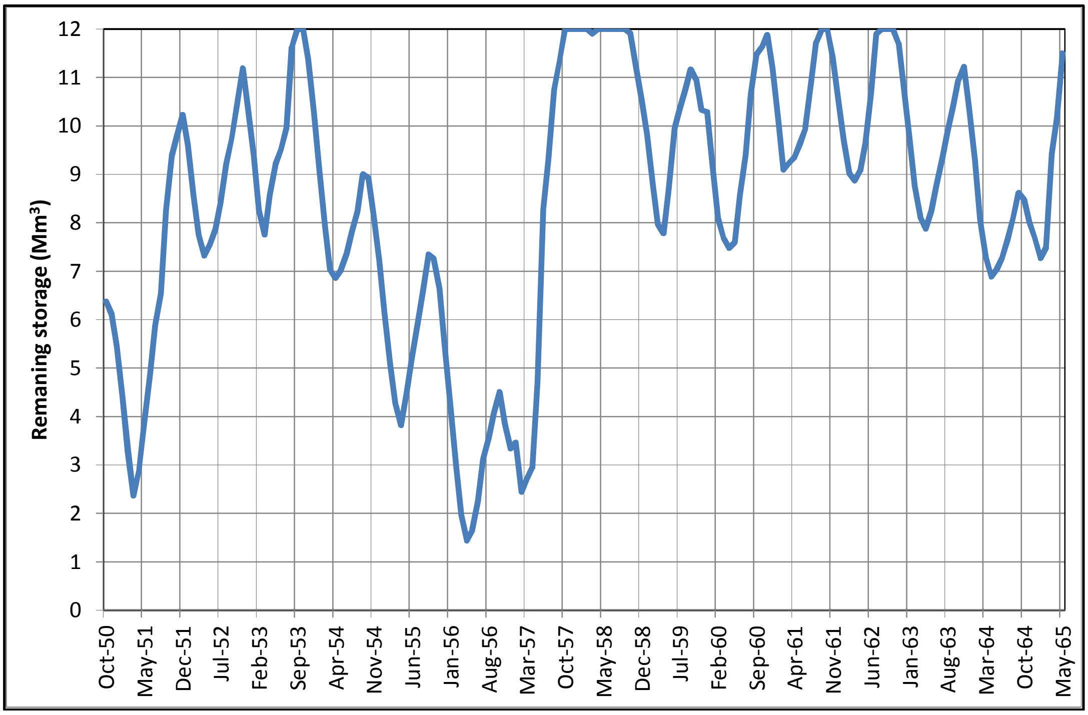

Figure 19: Little Valley Creek West dam storage dynamics

Modelling shows that a new Lower Manor Burn dam would refill every year. 5 Mm^3 of usable storage should be sufficient to meet Galloway Irrigation Scheme demand. If the dam were located 400 m upstream of the existing dam, a maximum dam water level of 169 m amsl would provide 5 Mm^3 of usable storage (see Figure 13). This would require about a 20 m high dam. The disadvantage of this dam site is it would affect the existing natural ice skating rink. If the dam were instead constructed 1.4 km upstream of the existing dam, upstream of the natural ice skating rink, the maximum dam water level would need to be 174 m amsl in order to provide 5 Mm^3 of usable storage. This would require about a 25 m high dam.

Modelling shows that the Little Valley Creek West dam would require about 12 Mm^3 of usable storage. This would require about a 25 m high dam. The dam would not refill every year and consequently could be susceptible to supply difficulties if climate change resulted in a shift to a drier climate. If this dam site were selected, we recommend a flow recorder site be set up near the dam site, and flows be recorded for a minimum of three years.

3 Flood flows

The lack of flow recorders in the Manor Burn catchment means there is considerable uncertainty in flood flow estimates. Installing flow recorder(s) in the catchment would allow flood estimates to be refined. In lei of actual data we used the method of McKerchar and Pearson (1989). McKerchar and Pearson's core assumption is:

$$Q_{T2} = Q_{T1}\left(\frac{A_2}{A_1}\right)^{0.8}$$

Where
Q_{Ti} = Flood flow with return period T for catchment i (m^3/s)
A_i = Area of catchment i (km^2)

We have used the Manuherikia catchment at Ophir for Catchment 1. For Ophir:
$\overline{Q} / A^{0.8}$ = 0.41
$Q_{100} / \overline{Q}$ = 3.3
$Q_{500} / \overline{Q}$ = 4.2

Further details on Manuherikia at Ophir flood flows are given by Aqualinc (2012d).

Table 6: Estimated Manor Burn dam flood flows

Parameter	Hope Creek dam	Lower Manor Burn dam	Little Valley Creek West dam
Catchment area (km^2)	88	400	40
Mean annual flood (m^3/s)	15	50	8
Q_{100} (AEP = 0.01) (m^3/s)	49	167	26
Q_{500} (AEP = 0.002) (m^3/s)	62	212	33

Based on McKerchar and Pearson (1989)'s study, we estimates these estimates to be accurate to ±30.

Dam flood storage may significantly reduce peak flows; the degree of reduction would depend on the spillway hydraulic characteristics.

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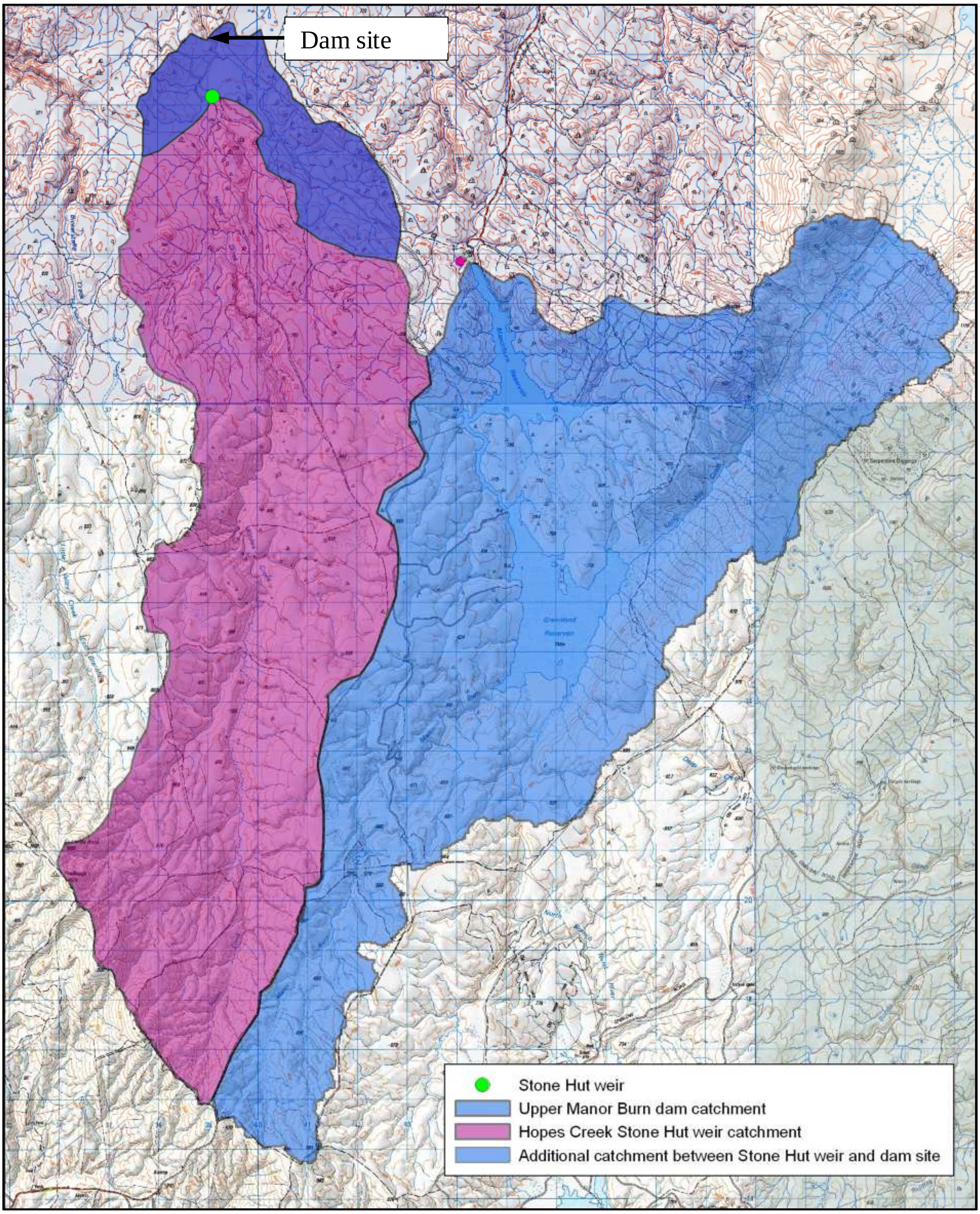
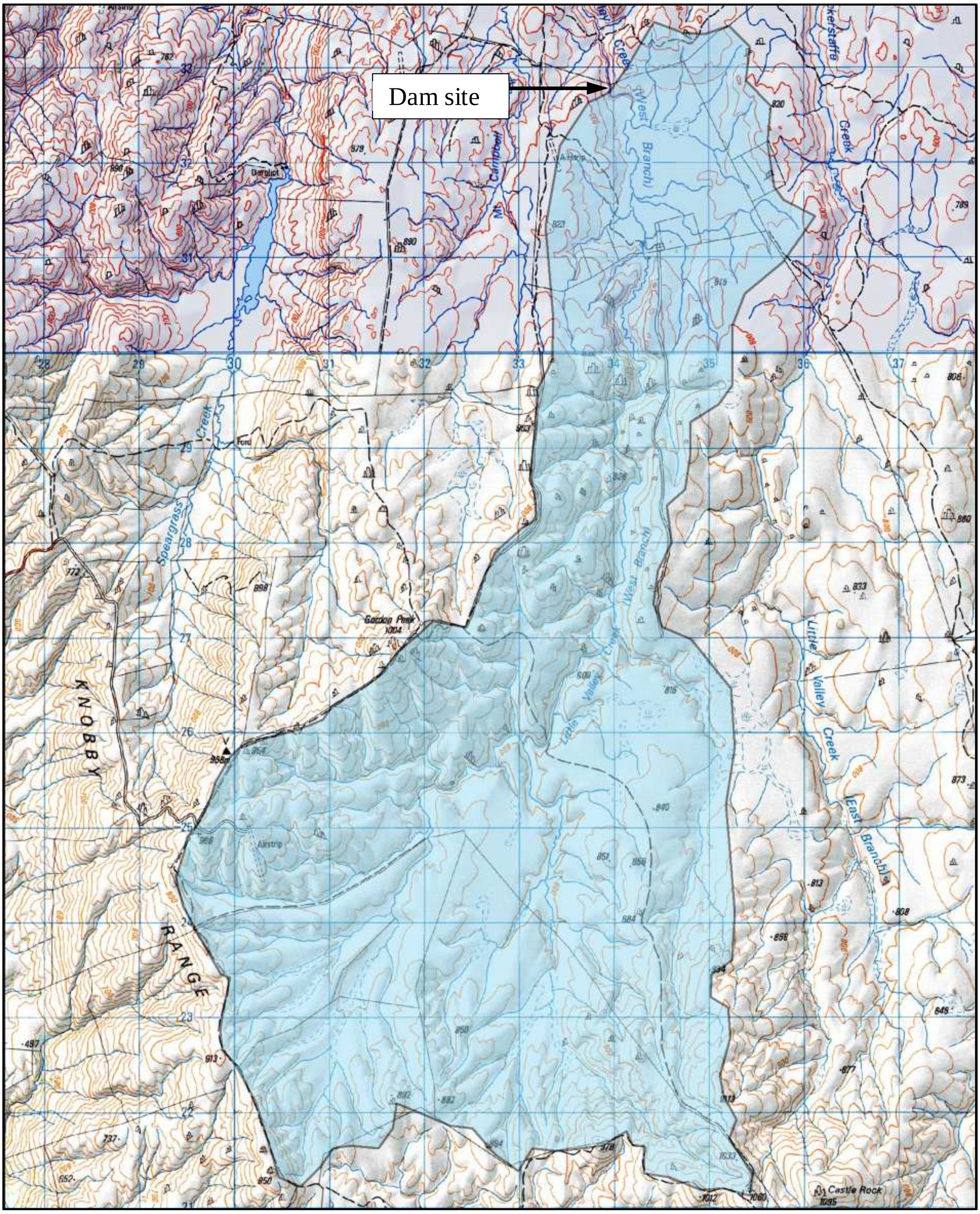
Appendix A: Catchment boundaries



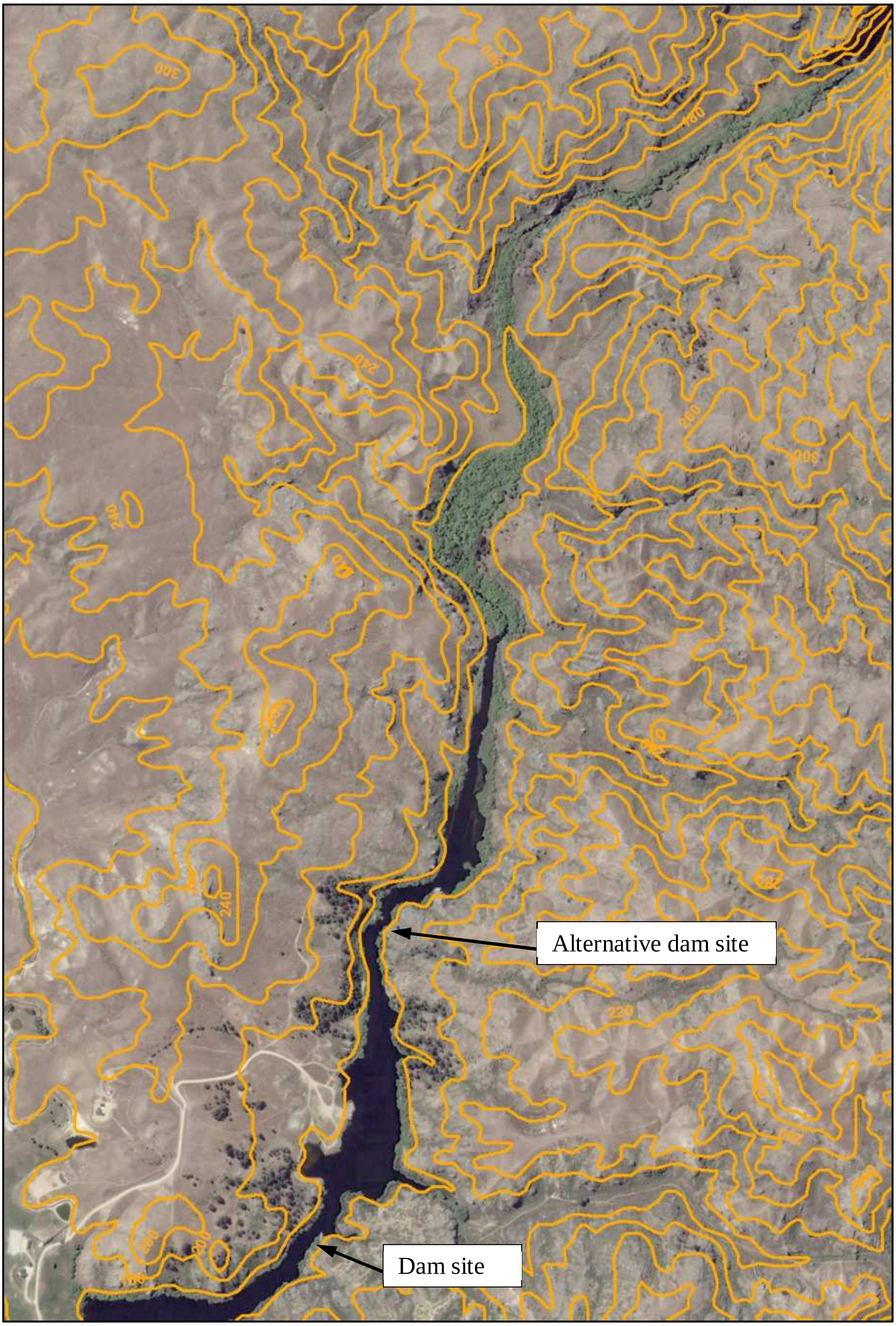
Hope Creek Dam and Upper Manor Burn dam catchments



Little Valley Creek West dam catchment

Appendix B: Stone Hut Flat

Appendix C: Lower Manor Burn dam



Appendix D: Little Valley Creek West basin